Acoustic propagation studies in the Windy Islands Soliton Experiment (WISE)

Ching-Sang Chiu
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943-5001
Phone: (831) 656-3239 Fax: (831) 656-7970 E-mail: chiu@nps.edu

D. Benjamin Reeder
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943-5001
Phone: (831) 656-3268 Fax: (831) 656-2712 E-mail: dbreeder@nps.edu

Award #: N0001405WR20201

LONG-TERM GOAL

Our long-term research objectives are: (1) Characterization of meso- to internal-wave-scale oceanographic processes which influence broadband sound transmissions in a coastal environment. Central to the characterization are the formulation of accurate forward relations and the quantification of the sensitivities and variability of the various observable acoustic quantities in relation to environmental differences and changes. (2) Development and improvement of high-resolution tomographic inverse techniques for measuring the dynamics and kinematics of meso- and finer-scale sound speed structure and ocean currents in coastal regions. (3) Understanding of three-dimensional sound propagation physics in a highly variable coastal region, including horizontal refraction and azimuthal coupling, with the ultimate goal of accurate prediction of acoustic propagation within this complex environment. (4) Characterization of the variability in the acoustic propagation over long ranges in the deep basin of the South China Sea (SCS), in the presence of large non-linear internal waves and solitons.

OBJECTIVES

This effort is part of a large, international program called the Windy Islands Soliton Experiment (WISE). In collaboration and coordination with other U.S. and Taiwan investigators participating in WISE, we have continued to carry out rigorous measurements and analysis of nonlinear internal waves and their effects on low frequency acoustic propagation in the Northeastern (NE) South China Sea.

The WISE program consists of two separate sound transmission experiments—one over the shallow shelf and one across the deep basin along a physical oceanography mooring transect. The objective of the shelf transmission experiment, which occurred in April 2005, was to study the physics of sound propagation through nonlinear, elevation internal waves in shallow water, and to quantify the associated fluctuations in the sound intensity. The objective of the deep basin, long-range transmission experiment, which is still ongoing, is to study and characterize the supertidal-to-seasonal-scale impacts of the trans-basin, nonlinear internal waves on long-range transmission loss, and to help monitor the evolution of the trans-basin internal waves in the basin's interior.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Acoustic propagation studies in the Windy Islands Soliton Experiment (WISE)**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Department of Oceanography,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

The shelf transmission was carried out prior to the basin transmission in April 2005. This was a short, 3-day experiment to study the effects of nonlinear elevation waves on acoustic propagation. The approach was to make simultaneous, high-resolution observations of both the acoustic propagation and physical oceanography in the experimental site. Both moored and shipboard oceanographic observations were made, with sufficient spatial and temporal resolution. Simultaneously, acoustic signal transmissions, aiming at achieving sufficient realizations and spatial coverage through the internal waves, from both a moored source and mobile sources to a moored vertical line array (VLA) of hydrophones, as well as sonobuoys, were performed.

The analysis of the shallow-water data commenced soon after the April 2005 cruise. The VLA data was first pulse-compressed and motion-compensated, and then analyzed for sound intensity as a function of depth and time. Characterizations of the observed intensity fluctuations, in terms of both phenomenology and statistics, are currently being made. In parallel, the oceanographic measurements obtained along the transmission paths are being analyzed using empirical-decomposition and time-series methods to deduce the space-time structure of the sound-speed changes produced by the elevation internal waves. Finally, a coupled normal-mode model will be employed to examine the propagation physics by linking the observed sound-speed structure to the observed features and statistical properties of the intensity fluctuations.

The deep basin transmission experiment commenced immediately following the completion of the shelf experiment. Major equipment for the basin experiment consists of two acoustic transceivers on integrated acoustic and physical oceanography moorings. The two transceivers began transmitting and receiving phase-modulated signals in May 2005, to capture multi-scale variability in the transmission loss. A hypothesis under this investigation is that a major portion of this acoustic variability is induced by the evolution of the trans-basin internal tides and waves that are modulated by mesoscale oceanographic events and seasonal cycles. The length of this reciprocal transmission path is approximately 160 km across the NE SCS basin.

The analysis of the basin transmission has already commenced, following the retrieval of the initial data set from the first re-deployment cruise in July 2005. The basin data is first processed for the pulse arrival structure as a function of transmission time, with motion compensation applied in the processing. Using these pulse responses, time series of transmission loss and of travel times of individual arrivals are being derived and their multi-scale variability analyzed. In addition to characterizing the annual acoustic variability, the basin data will be employed to help analyze the trans-basin internal tides and wave packets using standard tomography techniques. To achieve this, a ray-based propagation model, after calibration by the sonobuoy-transect data, will be used to simulate the eigenrays and the "reference" arrival structure. Identification of the ray arrivals, followed by inversion of the reciprocal travel-time data, is being performed.

WORK COMPLETED

The shelf experiment was successfully completed in April 2005. In it, a moored source, a moored vertical line hydrophone array, moored temperature strings and a towed Scanfish CTD were employed to obtain simultaneous measurements of the fluctuating acoustic signal intensity and of the variable sound speeds for a period of three days. Other U.S. and Taiwan acousticians contributed additional and highly complementary acoustic measurements with autonomous mobile acoustic sources (MAS), sonobuoys and a bottom-mounted hydrophone (BMH).

The basin experiment began in April 2005 and will continue to the end of October 2007. It has entailed seasonal cruises to maintain two moored acoustic transceivers that reciprocally and periodically transmit a signal across the basin. Additionally, during the deployment cruise for the basin moorings, sonobuoys were systematically dropped along the transmission path to measure transmission loss versus range.

While most of the effort by our research team has focused on the seasonal cruises to recover data and redeploy the moorings, work completed in FY06 includes (1) processing a portion of the acoustic signals received at mooring B1 in the deep basin, (2) analysis of the temperature string data from mooring B1 for the internal wave-induced perturbation spatial and temporal structures, and (3) initial analysis of the seasonal variability in the travel times of the acoustic signals propagating across the basin between moorings B1 and B2. Data analysis and modeling will become our exclusive focus in FY07 following the final recovery of the acoustic transceivers in October 2006.

RESULTS

Figure 1 shows the configuration of the mooring transect, deployed in April 2005. Moorings B1 and B2 are the acoustic moorings.

Figure 2 shows the initial results of the acoustic transmissions between moorings B1 and B2 for the period of March 1 to May 15, 2006. These are the arrival structures of the signals received in the broadside beam at mooring B1. Neglecting mooring motion, the .3 second decrease in travel time between March 1 and May 15 represents an approximate increase in average water temperature of $1^{o}C$ along the propagation path within the deep sound channel. This is consistent with the seasonal warming trends measured by the temperature instruments during the period.

Figure 3 shows single phone arrival structures at B1 for four specific moments during the period March 1 to May 15, 2006. The four curves at each location in time are single-phone coherent averages, which are an indication of the different paths traveled by the acoustic signals to each of the four hydrophones in the acoustic array. The change in the structure of the arrivals reflect a change in the multi-path propagation over the 2 ½ month period. This variability will be investigated further and compared to acoustic propagation modeling results using the environmental parameters measured during the same period.

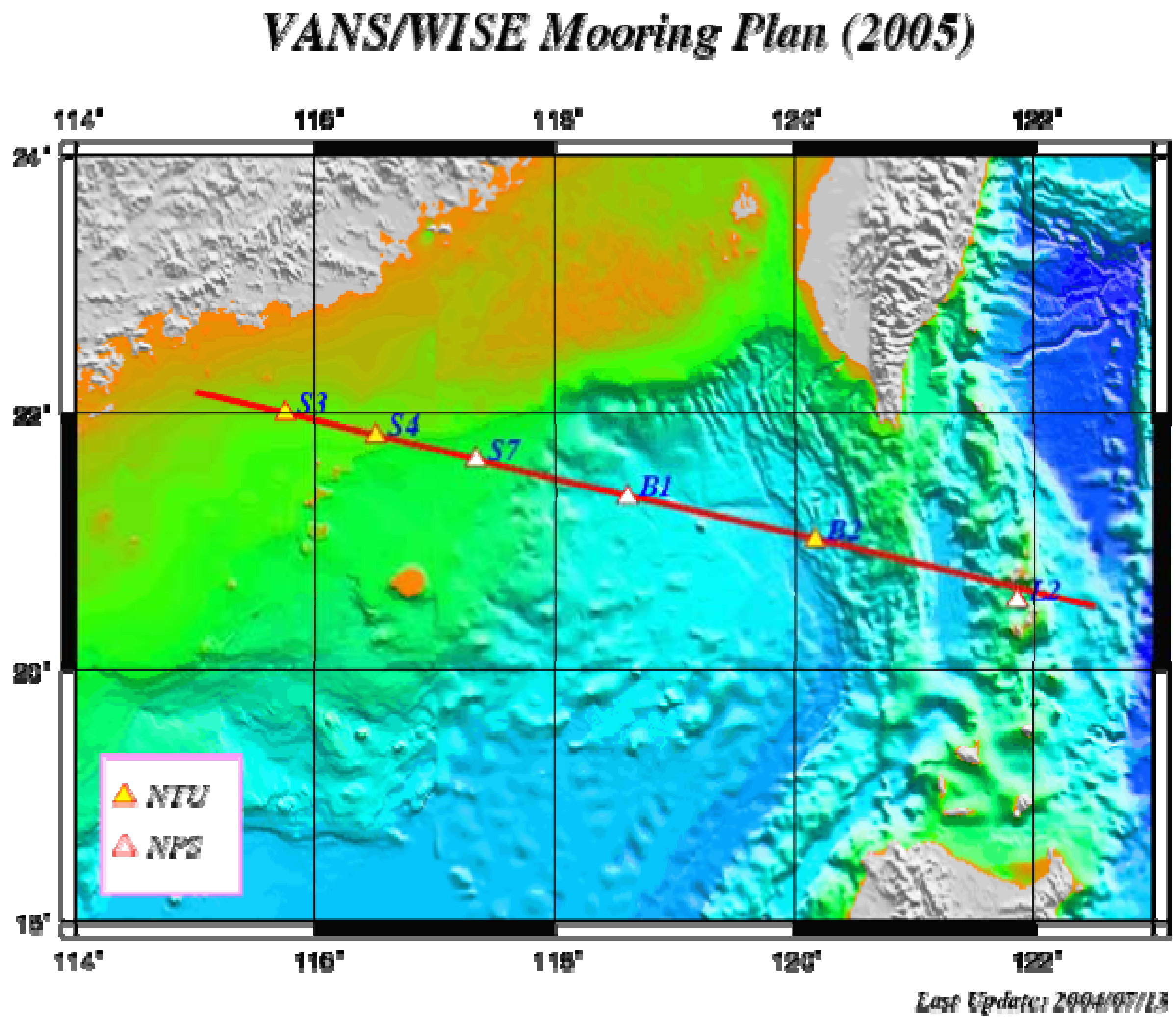

Figure 1. Configuration of the mooring transect, deployed in April 2005. Moorings B1 and B2 are the acoustic moorings.

Broadside Coherent Arrival Structures at Mooring B1

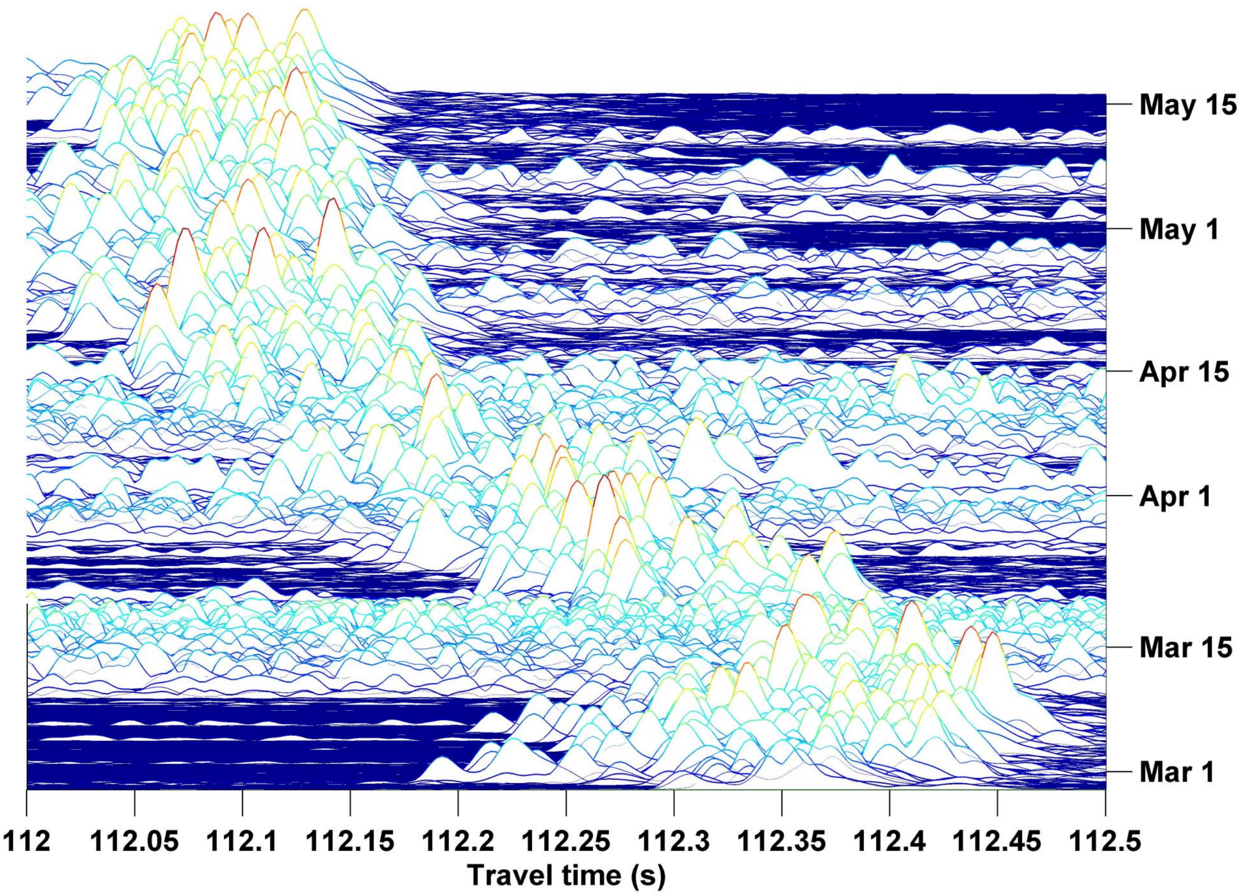

Figure 2. Fixed-fixed transmission initial results for the period of March 1 to May 15, 2006, showing the arrival structures of the signals received in the broadside beam at mooring B1. Neglecting mooring motion, the .3 second decrease in travel time between March 1 and May 15 represents an approximate increase in average water temperature of 1^{o}C along the propagation path within the deep sound channel

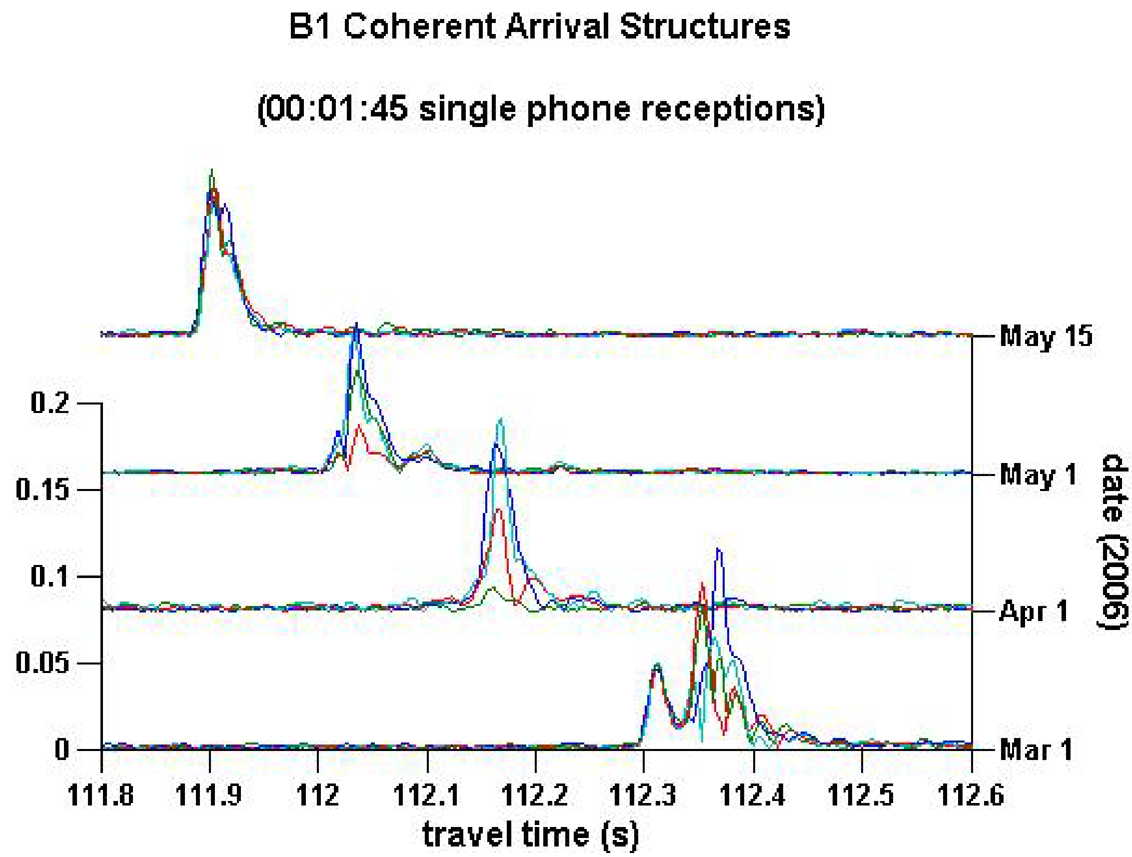

Figure 3. Single phone arrival structures at B1 for four specific moments during the period March 1 to May 15, 2006. The four curves at each location in time are the single-phone coherent averages, showing the change in the multi-path structure over the 2 ½ month period.

IMPACT/APPLICATIONS

The oceanographic and acoustic data gathered in this field study will be valuable in helping to create models of shelf-break regions suitable for assessing present and future Navy acoustic and non-acoustic systems.

RELATED PROJECTS

This fully integrated acoustics and oceanography experiment should significantly extend the findings and data from SWARM, Shelfbreak PRIMER and ASIAEX, thus improving our knowledge of the physics, variability, geographical dependence and predictability of sound propagation in a shelf-slope environment.

PUBLICATIONS

Schneck-Scott, A.R., "Detection and Resolvability of Pulsed Acoustic Signals through the South China Sea Basin: A Modeling Analysis," Naval Postgraduate School Master Thesis, September 2005.